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SUBJECT: Trip Report - Conference with  
Dr. W. G. Shepherd, University of  
Minnesota, on Space Materials and  
Manufacture - Case 103

DATE: November 27, 1968

FROM: F. G. Allen  
A. P. Vernon

ABSTRACT

An all-day conference was held with Dr. W. G. Shepherd and his associates at the University of Minnesota to discuss the STAC Winter Study in the subject discipline. The group felt that a research and development facility should be planned on early manned stations to explore possible new processes and materials that may be feasible in zero-g. It also felt that the term "Space Manufacturing" should be changed to reflect the fact that early research and development, not actual manufacturing, should be considered for the near future.

(NASA-CR-100220) TRIP REPORT - CONFERENCE  
WITH DR. W. G. SHEPHERD, UNIVERSITY OF  
MINNESOTA, ON SPACE MATERIALS AND  
MANUFACTURE (Bellcomm, Inc.) 8 P



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MEMORANDUM FOR FILE

Messrs. F. G. Allen, M. H. Skeer, D. Sortland and A. R. Vernon held an all-day conference on November 7, 1968 at the University of Minnesota with Professor W. G. Shepherd and colleagues on the STAC Winter Study topic of Space Materials and Manufacturing Processes. The Minnesota group included Professors R. J. Collins, R. A. Swalin, W. T. Peria and G. Wehner. This group provided an excellent professional coverage for the fields of experimental electronics, lasers, optical technology, solid state physics, metallurgy, and surface physics.

The discussion covered 1) the overall plan for the STAC study, 2) a critical examination of each of the proposed ideas for space materials processing listed in Appendix 1, and 3) a brief discussion of possible manufacturing on the lunar surface.

The tentative conclusions on the 20 ideas in Attachment 1 can be summarized by the priority listing and comments give in Table 1.

Criticism of Term "Manufacturing in Space"

After most of these topics had been discussed, the feeling emerged from the group that the interesting and exciting aspects of this area are the research and early experimentation with new materials and processes; the expression "Manufacturing in Space" is a misrepresentation of what is worth trying for the near future.\* The expression calls to mind large punch presses and lathes for volume production of highly developed products, and it is clear that this sort of thing simply cannot happen for a long time, if ever, in space. What can happen, and it can have great significance, is the early demonstration and trial of totally new forming and processing capabilities and the later production, with these capabilities, of

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\* Exactly this same opinion was voiced by the industrial representatives at the November 1, 1968 conference on this topic at MSFC.

TABLE I - TENTATIVE RATINGS OF ZERO-G PROCESSES

PRIORITY NO.	TITLE	COMMENTS
1	Levitation melting, possibly combined with vacuum distillation.	Large quantities possible in space; no restrictions on conductivity. Many new refractory materials of interest (m.p. > 2000°C). Absence of crucible a major advantage.
2	Growth of long whiskers, dislocation-free, high strength; crystal growing from vapor.	Zero-g permits vapor-liquid-solid processes not available on earth.
3	Crystal growing from liquid; floating zone refining.	Absence of thermal convection in growth from melt or molten zone may improve chances for dislocation-free crystal. Larger crystals can be grown by floating zone than on earth.
4	Blending, alloying, and conversion of compacted powder into castings; composite casting.	Zero-g may permit significant new materials.
5	Forming thin wall membranes and castings; vapor casting.	May be of interest for optical surfaces for use in space.

TABLE I (Continued)

PRIORITY NO.	TITLE	COMMENTS
6	Use of zero-g and vibration free environment to cast large and perfect optical elements.	May be of interest for use <u>in</u> space; doubtful for return to earth.
7.	Making light weight metal foams.	May be possible, but significant use of product either in space or on earth doubtful.
8	<p>Casting or blowing of hollow spheres and precision parts.</p> <p>Some types of physical testing.</p> <p>Liquid forming (forging, extrusion, etc.).</p> <p>Nuclear fuel processing using large, weightless centrifuges for isotope separation.</p> <p>Separation of transactinide elements by using superconducting magnets at cryogenic temperatures in space.</p> <p>Processes requiring a sterile or clean room atmosphere might be more easily performed in space.</p> <p>Reactive metals, catalysts, and pharmaceuticals might benefit from space preparation.</p>	All these processes left the Minnesota group unimpressed as to early interest or usefulness.

small quantities of valuable new materials with unusual properties.

It was urged that the title for this space activity emphasize the research on new materials and processes rather than manufacturing itself. The present authors are therefore proposing such titles as "Space Materials and Processing" or "New Materials and Manufacturing Processes in Space."

#### Lunar Surface Operations

In a brief discussion, it appeared that extraction of oxygen\* from lunar soil or rocks would be so desirable for future lunar or lunar-based operations, that likely processes should be studied even before lunar samples are returned. With samples available, the extraction process can be planned and costed out in detail, to compare with the expense of carrying it up from earth. Water, if found, can yield  $H_2$  and  $O_2$  very readily.

Excavation methods for shelters under the lunar surface and light weight construction materials from earth should be examined soon.

The possibility that metals such as iron or copper could be extracted simply from relatively pure ores on the lunar surface exists, and is very significant in planning construction of later lunar bases.

#### Interesting Technical Comments

During the course of discussion the following points of interest emerged.

1. Wehner points out that very perfect small hollow glass spheres are now available on the market and are relatively cheap.

2. Wehner points out that a single vacuum sputtering apparatus for Western Electric's manufacturing lines costs over one million dollars.

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\*Oxygen is already known to exist in lunar soil from the Surveyor alpha back-scattering experiment.

3. On the usefulness of space vacuum, it was pointed out that much of our expensive development of rapid valving, pump-down and feed-thru-of-motion procedures might have been by-passed if all processing could have been done in the open vacuum of space. But Shepherd answered that we could have constructed very large vacuum rooms on earth where a man could work either in a space suit in the vacuum or through a sophisticated micromanipulator from outside the vacuum room, if this was really so desirable. (Such a vacuum room may not be a silly idea itself, and could certainly be a good testing mode for any proposed use of space vacuum.)

On the question of the rapid pump-down and high-through-put capacity of space, it was decided that a large vacuum room with cryogenically cooled walls on all sides could simulate space pumping very closely even up to loads of many millimeters of absorbed material on the walls. However, auxilliary pumps will be needed for helium or hydrogen and possibly some noble gases which do not absorb and liquify readily. (This approach is, of course, expensive.)

It was felt that processing very large surfaces might eventually be done profitably in space vacuum. Two examples cited were producing very large area solar-cell surfaces, or aluminizing large reflector surfaces, both for space use.

4. On the subject of expensive materials in small quantities, Swalin informed us that United Aircraft now makes available tungsten fibres for high-strength composites at thousands of dollars per pound.

5. A short investigation should tell whether or not particle radiation levels in space - particularly high energy solar protons or cosmic ray particles - would introduce significant numbers of dislocations during the zero-g growth of dislocation-free crystals.

6. It was generally felt that one could not make a sensible argument for producing metal foams in space even if one learns how to, since larger volumes of the product would be required for any significant earth market than could be brought down from orbit, at least for the foreseeable future. The value per cubic foot of such material would not be high enough to justify its space manufacture.. A possible exception might be foams of very special properties that would make valuable devices in small quantities.

Conclusions

It was agreed that there are certain interesting possibilities for using new processes (such as levitation melting in zero-g) and growing new materials (such as new glasses, crystals and ceramics), that do deserve investigation in early manned space stations. The emphasis should be on basic research of the physics and chemistry of the new materials and processes, rather than on trying to manufacture any particular product.

What is needed is a versatile facility on the manned station to investigate some of the most fruitful ideas first. Controls with known materials (such as silicon) should be planned at the beginning.

Plans to manufacture large amounts of any materials or products in space should be discouraged for the present.

*F. G. Allen*  
F. G. Allen

*A. R. Vernon*  
A. R. Vernon

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Attachment  
Appendix I

## APPENDIX I

### MATERIALS AND PROCESSES TO BE CONSIDERED FOR SPACE MANUFACTURING

1. Growth of Long Whiskers
2. Levitation Melting
3. Floating Zone Refining
4. Crystal Growing from a Liquid
5. Crystal Growing from a Gas
6. Casting or Blowing of hollow spheres and precision parts
7. Forming Thin Wall Membranes and Castings
8. Making Light Weight Foams
9. Blending
10. Vacuum Distillation of Metals
11. Production of Miniature Integrated Circuits
12. Some Types of Physical Testing
13. Liquid Forming (forging, extrusion, etc.)
14. Conversion of compacted powder products into castings
15. Nuclear fuel processing using large, weightless centrifuges for isotope separation
16. Vapor Coating
17. Production of transactinide elements by using superconducting magnets at cryogenic temperatures in space
18. Utilize the Vibrationless motion available in space to produce perfect surfaces, such as of lenses or mirrors
19. Processes requiring a sterile or clean room atmosphere might be more easily performed in space
20. Reactive metals, catalysts, and pharmaceuticals might benefit from space preparation.